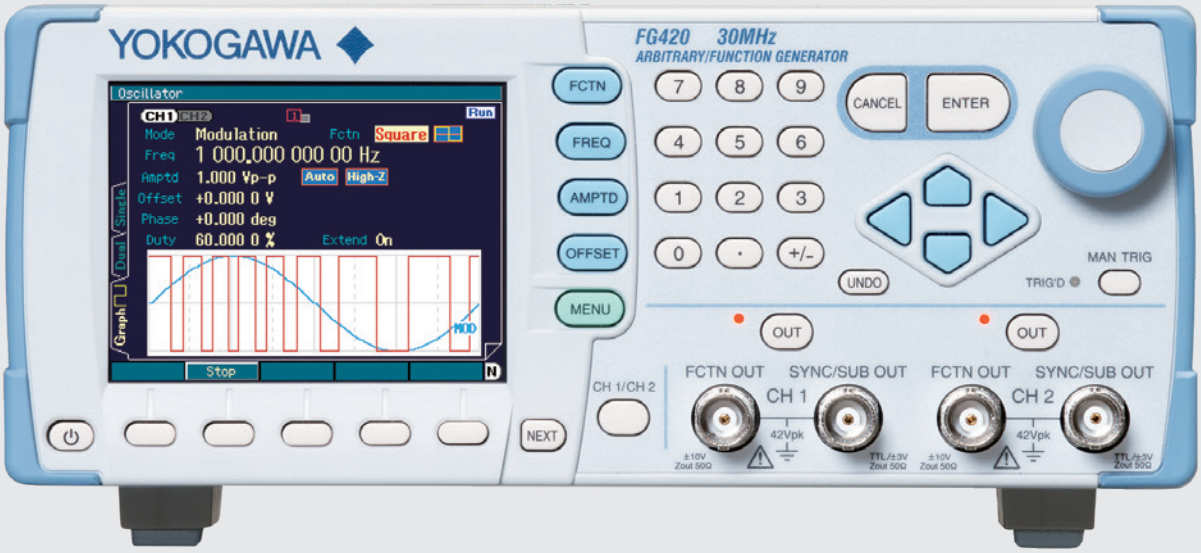
Test&Measurement

YOKOGAWA



How can you replicate real world signals? Precisely

FG400 Series
Arbitrary/Function Generator

- 0.01 µHz to 30 MHz, 20 Vp-p, 1 or 2 channels
- Intuitive operation with a 3.5” LCD screen
- Synchronize up to 6 units to provide up to 12 output channels
- A variety of sweeps and modulations

Bulletin FG400-01EN

nbn Austria GmbH

Features and benefits

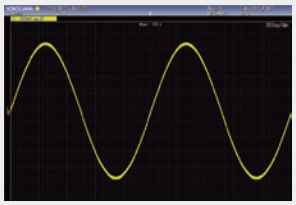
Easily generate basic, application specific and arbitrary waveforms.

The FG400 Arbitrary/Function Generator provides a wide variety of waveforms as standard and generates signals simply and easily.

There are one channel (FG410) and two channel (FG420) models. As the output channels are isolated, an FG400 can also be used in the development of floating circuits. (up to 42 V)

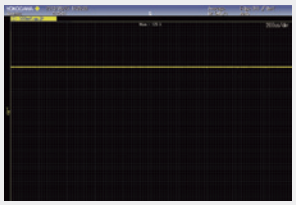
Basic waveforms

Sine



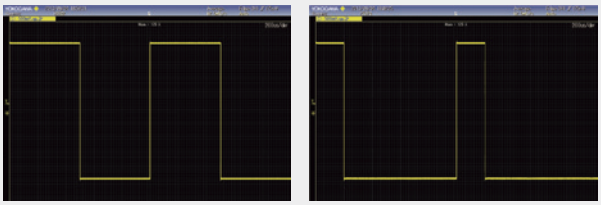
0.01 µHz to 30 MHz

DC



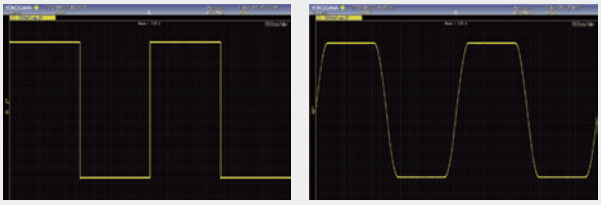
±10 V/open

Square



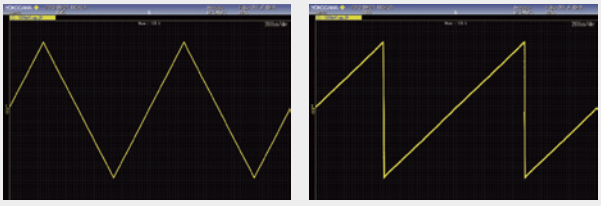
0.01 µHz to 15 MHz, variable duty

Pulse



0.01 µHz to 15 MHz, variable leading/trailing edge time

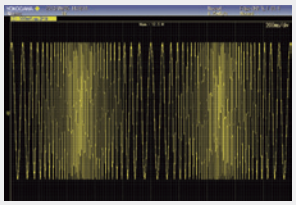
Ramp



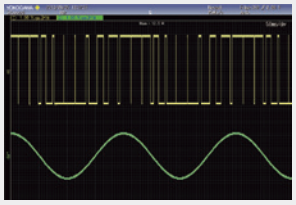
0.01 µHz to 5 MHz, variable symmetry

Advanced functions

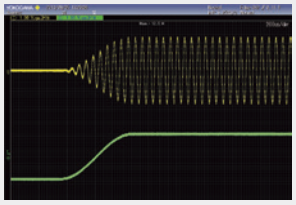
Sweep & Modulation



Frequency sweep
Setting items
start/stop frequency, time, mode (continuous, single, gated single), function (one-way/shuttle, linear/log)

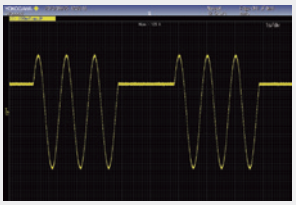


PWM
Setting items
carrier duty, peak duty deviation
Output duty
the range of carrier duty ±peak duty deviation

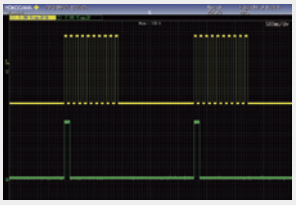


AM
Setting items
carrier amplitude, modulation depth
Output amp.
the range of amp./2 × (1 ±mod. Depth/100)

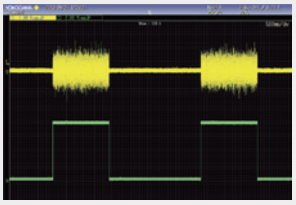
Burst



Auto
Oscillation and stop are automatically repeated with the respectively specified wave number.



Trigger
Oscillation with the specified wave number is done each time a trigger is received.



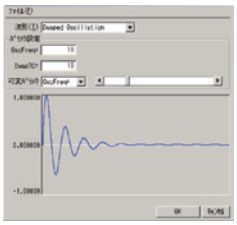
Gate
Oscillation is done in integer cycles or half cycles while the gate is on.

For trouble shooting

Arbitrary waveforms (16 bits amplitude resolution) of up to 512 K words per waveform can be generated. 128 waveforms with a total size of 4 M words can be saved to the internal non-volatile memory. Waveforms can be selected from the displayed list.
Waveforms can be created in the FG400 or with the editor software.

The list of arbitrary waveforms

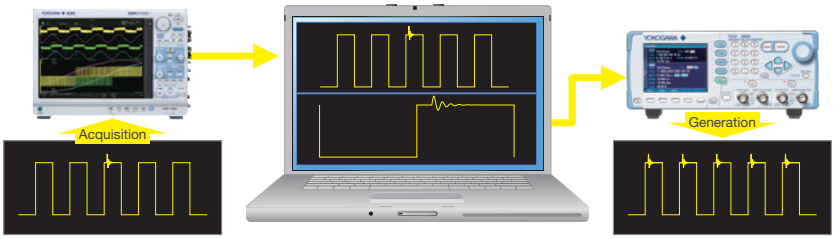
Editing screen in the FG400



Editing screen of the editor software

Acquire signal noise in the field, and then recreate it in the lab

The FG400 can generate signals as arbitrary waveforms that have been acquired by measuring instruments. Trouble shooting is made easier as the FG400 can generate waveforms that are difficult to reproduce. For example noise that only occurs on site.
With the XviewerLITE software (freeware), waveform (binary data) that is acquired using a YOKOGAWA DL950 or DLM5000 can be analyzed on the PC to find the abnormal waveform. This abnormal part can then be clipped, saved and generated using the FG400.



[Application]

Clipping the abnormal signal, then adding it to the normal signal

Connect the clipped abnormal signal output of channel 2 to the additional input terminal of channel 1, and then press the Manual trigger key. The abnormal signal is added to the normal pulse waveform that is set on channel 1.

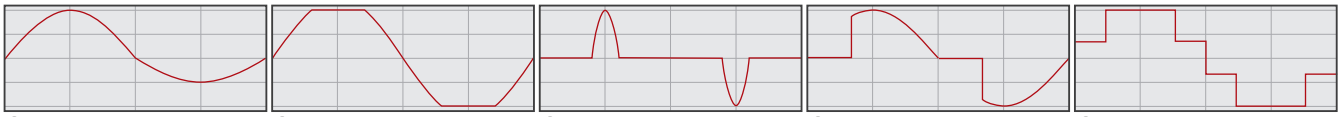
Features and benefits

Application-specific waveforms are also standard

Parameter-Variable Waveforms

In some cases engineers need application-specific waveforms like those needed to evaluate the response characteristics of mechanical/ electrical circuits and to emulate power supply circuits. The FG400 provides 25 different types of waveform as standard. As the parameters of application-specific waveforms can be changed like those of basic waveforms, waveforms are quicker and easier to generate.

Waveform name
• Variable Parameters



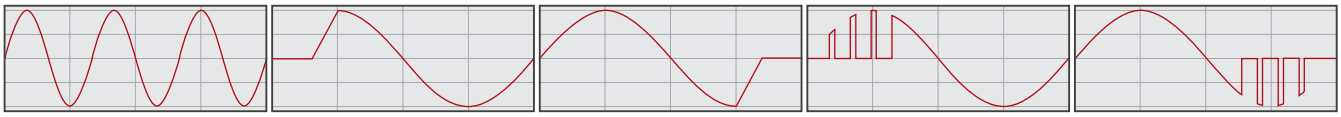
① Unbalanced sine
- First-half amplitude
- Second-half amplitude

② Clipped sine
- Clip rate

③ CF controlled sine
- Crest factor

④ Conduction angle controlled sine
- Conduction angle

⑤ Staircase Sine
- Number of steps



⑥ Multi-cycle sine
- Number of cycles
- Start phase

⑦ On-phase controlled sine
- Complete-on phase
- On-slope time

⑧ Off-phase controlled sine
- Off-phase
- Off-slope time

⑨ Chattering-on sine
- On-phase
- Number of chattering
- On-state time
- Off-state time

⑩ Chattering-off sine
- Off-phase
- Number of chattering
- On-state time
- Off-state time

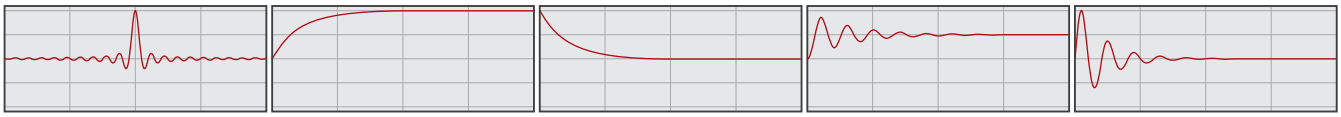
⑪ Gaussian pulse
- Standard deviation

⑫ Lorentz pulse
- Half value of width

⑬ Haversine
- Width

⑭ Half-sine pulse
- Width

⑮ Trapezoid pulse
- Slope width
- Upper base width



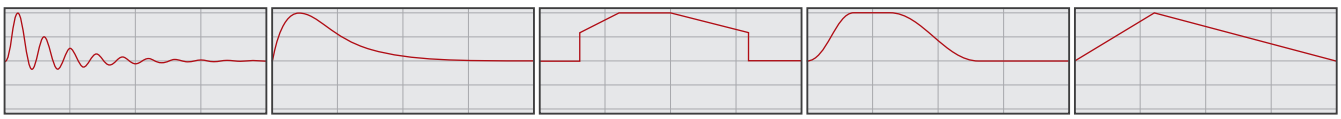
⑯ Sin(x)/x
- Number of zero crossings

⑰ Exponential rise
- Time constant

⑱ Exponential fall
- Time constant

⑲ Second order LPF step response
- LPF natural frequency
- LPF Q

⑳ Damped oscillation
- Oscillation frequency
- Damping time constant



㉑ Oscillation surge
- Oscillation frequency
- Damping time constant
- Trailing time constant

㉒ Pulse surge
- Rising time
- Duration time

㉓ Trapezoid with offset
- Leading delay
- Rising-slope width
- Upper base width
- Falling-slope width
- Offset

㉔ Half-sine edge pulse
- Leading edge time
- Trailing edge time
- Duty

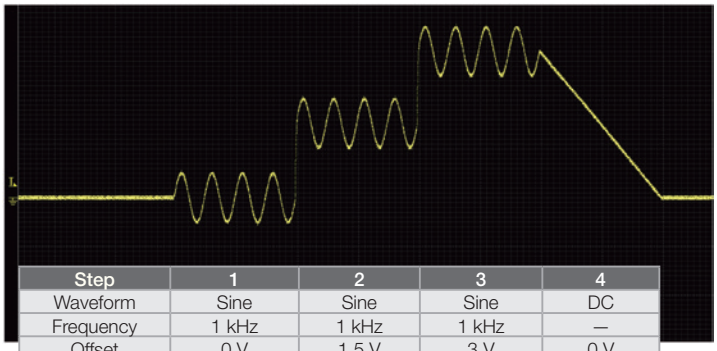
㉕ Bottom referenced ramp
- Symmetry

5

Manually program waveform patterns

Sequence function
Sequences of different waveform patterns can be generated by programming the parameters. Complex sequences can be easily created using the “Sequence Edit Software”.

Available parameters include:
waveform, frequency, phase, amplitude, DC offset, square wave duty, step time, hold operation, jump destination, number of jumps, step stop phase, branch operation, step termination control, step sync code output

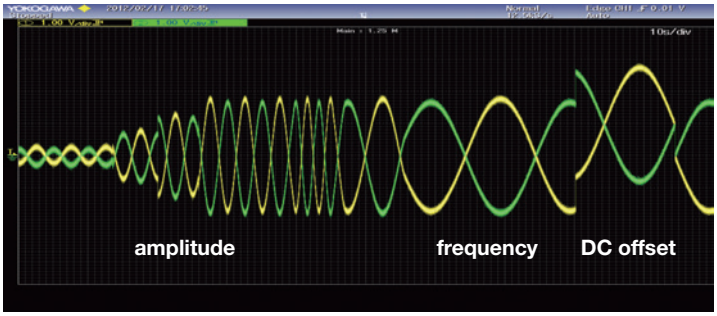


Step	1	2	3	4
Waveform	Sine	Sine	Sine	DC
Frequency	1 kHz	1 kHz	1 kHz	—
Offset	0 V	1.5 V	3 V	0 V
Sweep	—	—	—	ON

When 2 channels are linked (FG420 only)

In the FG420 the two output channels can be linked.
In this mode, both output signals vary when either channel is adjusted.

- Independent: Independent setting
- 2- phase: Holds the same frequency
- Constant frequency difference:
  Holds the frequency difference as a constant value
- Constant frequency ratio:
  Holds the frequency ratio as a constant value
- Differential output:
  Same frequency, amplitude, and DC offset. Reverse phase waveform

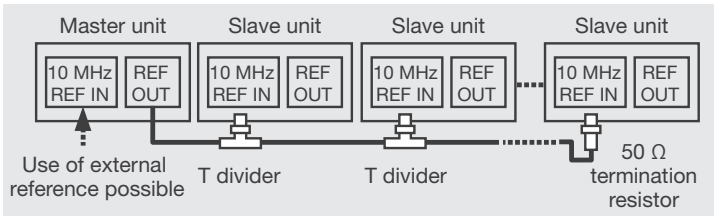


Example of the differential output

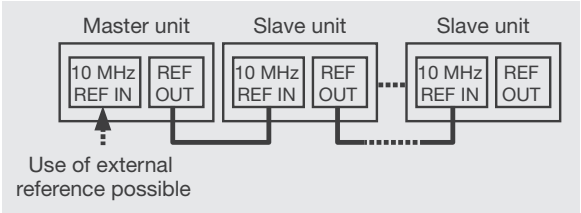
When you need more than 2 channels

By synchronizing multiple FG410 and FG420s, a generator of up to 12 phases (using six FG420s) can be created. The phase of each channel is synchronized to the master unit and can be individually adjusted.

Greater accuracy and stability
The FG400 has an external input terminal to increase frequency accuracy and stability by using a frequency reference with better accuracy than the built-in reference (for example, a rubidium frequency standard).



Connection method 1 (up to 6 units)



Connection method 2 (up to 4 units)

Input/output terminal

FG410 (1 ch)

FG420 (2 ch)

CH1 I/O terminals

1 Waveform output
2 Sync/sub-output
3 External modulation/addition input
4 External trigger input

Common I/O terminals

5 External 10 MHz frequency reference input
6 Frequency reference output
7 Multi-I/O connector
8 GPIB connector
9 USB connector

CH2 I/O terminals

10 Waveform output
11 Sync/sub-output
12 External modulation/addition input
13 External trigger input

Specification of FG400

Output and Oscillation Modes

Number of channels	FG410: 1 channel FG420: 2 channels
Output waveforms	Sine, square, pulse, ramp, parameter-variable waveform, noise (Gaussian distribution), DC, arbitrary waveform
Oscillation modes	Continuous, modulation, sweep, burst, sequence

Frequency

	Oscillation mode		
	Continuous, modulation, Sweep (Continuous, Single-Shot)	Sweep (Gated Single-Shot), Burst	Sequence
Sine	0.01 µHz to 30 MHz	0.01 µHz to10 MHz	0.01 µHz to10MHz
Square	0.01 µHz to 15 MHz	0.01 µHz to10 MHz	0.01 µHz to10MHz
Pulse	0.01 µHz to 15 MHz	0.01 µHz to10 MHz	not usable
Ramp	0.01 µHz to 5 MHz		0.01 µHz to 5 MHz*2
Parameter-variable waveform	0.01 µHz to 5 MHz		0.01 µHz to 5 MHz*2
Noise	Fixed to 26 MHz equivalent bandwidth		
DC	Frequency setting invalid		
Arbitrary	0.01 µHz to 5 MHz		

Frequency setting resolution	0.01 µHz
Frequency accuracy*1	±(3 ppm of setting + 2 pHz), Aging rate*1 ±1 ppm/year
Phase setting range	−1800.000° to +1800.000°

Output Characteristics

Amplitude	Setting range	0 Vp-p to 20 Vp-p/open, 0 Vp-p to 10 Vp-p/50 Ω AC+DC ≤ ±10 V/open
	Setting resolution	999.9 mVp-p or lower 4 digits or 0.1 mVp-p 1 Vp-p or higher 5 digits or 1 mVp-p
	Accuracy*1 *4	±(1% of amplitude setting [Vp-p] + 2 mVp-p)/open
	Setting units	Vp-p, Vpk, Vrms, dBV, dBm
	Resolution	Approx. 14 bits (36 mVp-p/open or higher)
DC offset	Setting range	±10 V/open, ±5 V/50 Ω
	Resolution	±499.9 mV or lower 4 digits or 0.1 mV ±0.5 V or higher 5 digits or 1 mV
	Accuracy*1	±(| 1% of DC offset setting [V] | + 5 mV + 0.5% of amplitude setting [Vp-p])/open (Sine, 10 MHz or lower, 20°C to 30 °C)
Output impedance	50 Ω, unbalanced	
Sync/sub output	Output voltage	Sync signals: TTL level Internal modulation signal: −3 V to +3 V/open Sweep X drive: 0 V to +3 V/open

Sine wave

Amplitude frequency characteristics*1	100 kHz or lower: ±0.1 dB 100 kHz to 5 MHz: ±0.15 dB 5 MHz to 20 MHz: ±0.3 dB 20 MHz to 30 MHz: ±0.5 dB (±0.8 dB at 2.8 Vp-p/50 Ω or higher) (50 mVp-p to 10 Vp-p/50 Ω, reference frequency 1 kHz)	
Total harmonic distortion*1	10 Hz to 20 kHz: 0.2% or less (0.5 Vp-p to 10 Vp-p/50 Ω)	
Harmonic spurious*1		0.5 Vp-p to 2 Vp-p/50 Ω / 2 Vp-p to 10 Vp-p/50 Ω
	1 MHz or lower	−60 dBc or lower / −60 dBc or lower
	1 MHz to 10 MHz	−50 dBc or lower / −43 dBc or lower
	10 MHz to 30 MHz	−40 dBc or lower / −30 dBc or lower
Non-harmonic spurious*1	1 MHz or lower −60 dBc or lower 1 MHz to 10 MHz −50 dBc or lower 10 MHz to 30 MHz −45 dBc or lower	(0.5 Vp-p to 10 Vp-p/50 Ω)

Square wave

Duty	Normal range	0.0100% to 99.9900% Upper limit (%): 100 − frequency (Hz) / 300,000 Lower limit (%): frequency (Hz) / 300,000 Jitter: 300 ps rms or less typ.
	Extended range	0.0000% to 100.0000% Jitter: 2.5 ns rms or less typ.
Rising/falling time*1	17 ns or less	
Overshoot	5% or less typ.	

Pulse wave

Pulse width	Duty setting range: 0.0170% to 99.9830% Time setting range: 25.50 ns to 99.9830 Ms	
Leading edge time, trailing edge time	Setting range	15.0 ns to 58.8 Ms (3 digits or 0.1 ns resolution) Leading/trailing edge time independently settable
	Minimum setting value	Largest of either 0.01% of period or 15 ns
Overshoot	5% or less typ.	
Jitter	500 ps rms or less typ. (10 kHz or higher) 2.5 ns rms or less typ. (under 10 kHz)	

Ramp wave

Symmetry setting range	0.00% to 100.00%

Parameter-variable waveform

Waveform group	Waveform name
Steady sine group	Unbalanced sine, Clipped sine, CF controlled sine, Conduction angle controlled sine, Staircase sine, Multi-cycle sine
Transient sine group	On-phase controlled sine, Off-phase controlled sine, Chatteringon sine, Chatteringoff sine
Pulse group	Gaussian pulse, Lorentz pulse, Haversine, Half-sine pulse, Trapezoid pulse, Sin(x)/x
Transient response group	Exponential rise, Exponential fall, Second order LPF step response, Damped oscillation
Surge group	Oscillation surge, Pulse surge
Other waveform group	Trapezoid with offset, Half-sine edge pulse, Bottom referenced ramp

Arbitrary waveform

Waveform length	4 K to 512 K words (2^n, n = 12 to 19) or 2 to 10,000 control points (linear interpolation between control points)
Total waveform saving capacity	Up to 128 waveforms or 4 M words (combined total for channels 1 and 2) saved to non-volatile memory
Amplitude resolution	16 bits
Sampling rate	120 MS/s

Modulation

Type	FM	Carrier waveform:	Standard waveform other than noise, pulse wave and DC, and arbitrary waveform
		Peak deviation:	0.00 µHz to less than 15 MHz
	FSK	Carrier waveform:	Standard waveform other than noise, pulse wave and DC, and arbitrary waveform
		Hop frequency:	Within settable carrier waveform frequency range
	PM	Carrier waveform:	Standard waveform other than noise and DC, and arbitrary waveform
		Peak deviation:	0.000° to 180.000°
	PSK	Carrier waveform:	Standard waveform other than noise and DC, and arbitrary waveform
		Deviation:	–1800.000° to +1800.000°
	AM	Carrier waveform:	Standard waveform other than DC, and arbitrary waveform
		Modulation depth:	0.0% to 100.0%
	DC offset	Carrier waveform:	Standard waveform and arbitrary waveform
		Peak deviation:	0 V to 10 V/open
	PWM	Carrier waveform:	Square wave, pulse wave
		Peak deviation	
		Square wave:	Normal variable duty range 0.0000% to 49.9900%
			Extended variable duty range 0.0000% to 50.0000%
		Pulse wave:	0.0000% to 49.9000%
Internal modulation waveform		Other than FSK, PSK:	Sine wave, square wave (50% duty), triangular wave (50% symmetry), rising ramp wave, falling ramp wave, noise, arbitrary wave
		FSK, PSK:	Square wave (50% duty)
Internal modulation frequency		Other than FSK, PSK:	0.1 mHz to 100 kHz (5 digits or 0.1 mHz)
		FSK. PSK:	0.1 mHz to 1 MHz (5 digits or 0.1 mHz)

Sweep

Sweep types	Frequency, phase, amplitude, DC offset, duty
Sweep functions	One-way (ramp waveform shape), shuttle (triangular waveform shape) (selectable) Linear, log (frequency sweep only) (selectable)
Sweep range setting	Start value and stop value specification or Center value and span value specification
Sweep time setting range	0.1 ms to 10,000 s (4 digits or 0.1 ms)
Sweep mode	Continuous, single-shot, gated single-shot (selectable) During gated single-shot, oscillation occurs only during sweep execution
Trigger source	Internal, external (selectable)
Internal trigger oscillator	Period setting range: 100.0 µs to 10,000 s (5 digits or 0.1 µs)
Stop level setting	Specification of signal level while oscillation is stopped during gated single-shot sweep Setting range: –100.00% to +100.00% of amplitude full scale or off
Sweep I/O	Sweep sync/marker output, Sweep X drive output, Sweep external control input, Sweep external trigger input

Burst

Burst mode	Auto burst, Trigger burst, Gate, Triggered gate (Gate oscillation switched on/off by gate upon trigger)
Number of Mark/Space	0.5 cycles to 999,999.5 cycles, in 0.5-cycle units
Oscillation stop unit during gate	1 cycle, 0.5 cycles (selectable)
Phase setting range	–1800.000° to +1800.000°
Stop level	Specification of signal level when oscillation is stopped. Setting range: –100.00% to +100.00% of amplitude full scale or off When the stop level is set to off, stop occurs at the set oscillation start/stop phase.
Trigger source	Internal, external (selectable). Manual trigger possible
Internal trigger oscillator	1.0 µs to 1,000 s (5 digits or 0.1 µs)
Trigger delay	0.00 µs to 100.00 s (5 digits or 0.01 µs) Latent delay of 0.55 µs, Only valid for trigger burst
External trigger input	TTL level Input impedance 10 kΩ (pulled up to +3.3 V), unbalanced
Manual trigger	Panel key operation

Sequence

Step control parameters	Step time, hold operation, jump destination, number of jumps, step stop phase, branch operation, step termination control, step sync code output
Intra-step channel parameters	Waveform, frequency, phase, amplitude, DC offset, square wave duty
Usable waveforms	- Sine wave, square wave, noise, DC, and arbitrary wave - Ramp wave and parameter-variable waveform can be used through saving as arbitrary waveforms.
Maximum number of usable waveforms	128
Number of saved sequences	10 sequences (saved to non-volatile memory)
Number of steps	Maximum of 255 steps per sequence
Step time	0.1 ms to 1,000 s (4 digits or 0.01 ms)
In-step operations	Constant, keep, linear interpolation (except waveform switching)
Jump count	1 to 999 or infinite
Branch operation	Upon branch input, branching to specified destination step

2-channel ganged operation (FG420 only)

Channel modes	Independent, 2-phase (holds same frequency), Constant frequency difference, Constant frequency ratio, Differential output (Same frequency, amplitude, and DC offset. Reverse phase waveform.)	
Equivalent setting, same operation	Set two channels at the same time.	
Frequency difference setting range	0.00 µHz to less than 30 MHz (0.01 µHz resolution) CH2 frequency – CH1 frequency	
Frequency ratio N:M setting range	1 to 9,999,999 (for each of N and M) N:M = CH2 frequency:CH1 frequency	
Phase synchronization	Automatically executed during channel mode switching	

Other functions

External 10 MHz frequency reference input	Voltage/waveform	0.5 Vp-p to 5 Vp-p, Sine wave or square wave
Frequency reference output	for synchronizing multiple FG410, FG420 units.	
	Voltage/waveform	1 Vp-p/50 Ω square wave, 10 MHz
External addition input	Function to add the external signal to the waveform output signal.	
	Addition gain	×2/×10/off selectable The maximum output voltage range is fixed to 4 Vp-p (×2) or 20 Vp-p (×10).
	Voltage/waveform	–1 V to +1 V, DC to 10 MHz (–3 dB)
	Input impedance	10 kΩ, unbalanced
Multi input/output	Used for sweep and sequence control.	
Synchronization of multiple units	Sync operation is possible. Up to 6 units can be connected with BNC cables in the form of master/slave connections, using the frequency reference output and external 10 MHz frequency reference input.	
User-Defined Unit	Sets and displays the value in any unit, using a specified conversion expression.	
	Setting target	Frequency, period, amplitude, DC offset, phase, and duty
	Conversion expression	[(Setting target value) + n] × m, or [$\log_{10}$ (setting target value) + n] × m Specification of conversion expression and values of n and m
	Unit character string	Up to 4 characters
Setting saving capacity	10 settings (saved to non-volatile memory)	
Interface	GPIB, USBTMC (SCPI-1999, IEEE-488.2)	

General Characteristics

Display	3.5 inch TFT color LCD*5
Input/output ground	- The signal grounds for waveform output, sync/sub output and external modulation/addition input are insulated from the housing. (42 Vpk max. These signal grounds are common within the same channel.) - The signal ground for the external 10 MHz frequency reference input is insulated from the housing. (42 Vpk max.) - Each signal ground for CH1, CH2 and external 10 MHz frequency reference input is independent.
Power supply	AC 100 V to 230 V ±10% (250 V max.) 50 Hz/60 Hz ±2 Hz
Power consumption	FG410 50 VA or less FG420 75 VA or less
Operating temperature/humidity range	0ºC to +40ºC, 5%RH to 85%RH (Absolute humidity of 1 g/m³ to 25 g/m³, no condensation)
Weight	Approx. 2.1 kg (main unit excluding accessories)
Dimensions	216 (W) × 88 (H) × 332 (D) mm (excluding protrusions)

Sequence Editor

Editing functions	• Initializes, copies, pastes, inserts, and deletes steps • Saves and reads sequence data to/from a file. • Sequence can be edited without connecting the device.
Displaying functions	• Editing screen: Lists parameters for each step. • Sequence view screen: Graphs changes of up to five parameters.
Transferring functions	• Transfers and reads sequence data to/from the device. • Transfers to the device the arbitrary waveform used in the sequence.
Device control functions	• Output on/off • Starts, stops and holds the sequence. • Can monitor the execution status of sequence.
Operating environment	• Windows 8.1/10 • USB interface • NI-VISA from National Instruments USB driver (required)

Arbitrary Waveform Editor

Editing functions	• Generation (standard waveform and a mathematical expression) • Interpolation (straight line, spline, and continuous spline) • Math operation (addition, subtraction, multiplication, and division of waveform) • Contraction and extension (vertical and horizontal directions) • Cuts, copies, and pastes some part of waveform • Undo function • Saves and reads arbitrary waveform data to/from a file. • Waveforms can be edited without connecting the device.
Display functions	• Zoom in/out • Scroll • Display unit (coordinates) selectable • Cursor (A, B)
Transfer function	• Transfers and reads arbitrary waveform data to/from the device.
Device control function	• Major parameter setting
Operating environment	* Same as the operating environment for the Sequence Editor.

XviewerLITE*3

Functions	• Reads the waveform data. (WVF/WDF format) • Displays the waveform. (main, zoom, history and X-Y) • Saves the waveform data to ascii and text. • Displays the waveform parameter value. • Cursor
Operating environment	• Windows 8.1/10 • USB interface (USB driver)

• Unless otherwise specified, the value assumes the following conditions: continuous oscillation, load of 50 Ω, DC offset setting of 0 V, auto range, waveform amplitude range of ±FS, external addition turned off; the AC voltage is rms value.

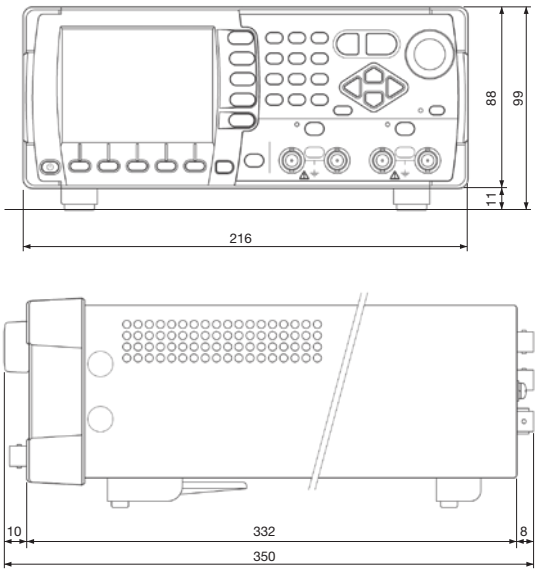
*1: Guaranteed numerical value. Other numerical values are nominal or typcal (typ.) values.
*2: Used after converted into arbitrary waveform.
*3: It can be downloaded from the web site.
*4: Condition: 1 kHz sine, amplitude setting of 20 mVp-p/open or higher.
*5: The LCD may include a few defective dots (5 dots or less).

Model	Suffix Code	Description
FG410		Arbitrary/Function Generator: 1-Channel, 30 MHz
FG420		Arbitrary/Function Generator: 2-Channel, 30 MHz
Power cord	-D	UL/CSA standard, PSE
	-F	VDE standard
	-R	AS standard
	-Q	BS standard
	-H	GB standard
	-N	NBR standard

Standard Accessories;
Power cord (1 set), User's manuals and application software (1 set)

Model/ parts number	Product	Description
705928	Multi input/output cable	For sweep/sequence control
751537-E2	Rack mount kit	Inch rack mounting (for 1 unit)
751537-J2	Rack mount kit	Millimeter rack mounting (for 1 unit)
751538-E2	Rack mount kit	Inch rack mounting (for 2 units)
751538-J2	Rack mount kit	Millimeter rack mounting (for 2 units)

Unit: mm



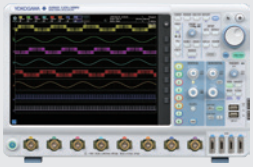
Related Products

ScopeCorder DL950

- Various modules for different measurement signals.
  - High-Speed 200 MS/s 14 bit Isolation Module
  - 6-ch Temperature/Voltage Input Module
  - CAN/CAN FD Moniter Module and etc.
- Up to 160-ch of multi-unit synchronized operation
- 8 G points large memory
- Real-time mathematical computation

Mixed Signal Oscilloscope DLM5000

- 8 analog channels + 16-bit logic
- 350 MHz, 500 MHz analog bandwidth
- Large 12.1-inch LCD display with touch screen
- Long memory: Up to 500 M points
- Two-unit connection function "DLMsync"



Mixed Signal Oscilloscope DLM3000

- Lightweight and compact
- 4 analog channels/3 analog channels + 8-bit logic
- 200 MHz, 350 MHz, 500 MHz analog bandwidth
- 8.4-inch LCD with touchscreen
- Long memory: Up to 500 M points

Notice

- Before operating the product, read the user's manual thoroughly for proper and safe operation.
- If this product is for use with a system requiring safeguards that directly involve personnel safety, please contact the Yokogawa offices.

This is a Class A instrument based on Emission standards EN61326-1, and is designed for an industrial environment.
Operation of this equipment in a residential area may cause radio interference, in which case users will be responsible for any interference which they cause.

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